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USING REAL-WORLD DATA AS A BASIS FOR PROBLEM-BASED LEARNING:
INVESTIGATING PRESERVATION BIASES OF FISH IN
FOSSIL BUTTE NATIONAL MONUMENT

by
Blair Larsen

A report submitted in partial fulfillment
of the requirements for the degree

of

Master's of Science

in

Applied Environmental Geoscience

Approved:

Utah State University
Logan, Utah

2009

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ABSTRACT

USING REAL-WORLD DATA AS A BASIS FOR PROBLEM-BASED LEARNING:
INVESTIGATING PRESERVATION BIASES OF FISH IN FOSSIL BUTTE
NATIONAL MONUMENT

by

Blair Larsen, Master's of Science

Utah State University, 2009

Major Professor: Dr. James P. Evans
Department: Geology

This project examined the design and development of an online problem-based learning module to teach earth-system science to K-12 educators. The module revolved around identifying earth sphere (lithosphere, hydrosphere, biosphere and atmosphere) interactions needed to produce mass fish mortality layers found in the Green River Formation at Fossil Butte National Monument. Students investigated the unique earth sphere combinations needed to produce mass fish mortality layers, reflected on the formation of such deposits, and examined the impact of these earth spheres on the earth system. As a supplement to the course, the students also analyzed data on fossils collected from a small research quarry on-site for potential fossil preservation bias, finding no clear bias in the sample data set. To gauge the effect of online problem-based learning on content knowledge, pre- and post-module assessments were given. The results

of the assessments are ambiguous in terms of content development, due to the small sample size. Much was learned about developing, marketing and teaching online and problem-based learning courses. Specific suggestions to improve the delivery and value of such courses include improving course scheduling by only offering the course in summer, training instructors and students on teamwork skills, and making the classroom value of the course more apparent to the students.

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Blair C. Larsen

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Introduction:

This paper reports on a project involving Earth system science education, online problem-based learning, taphonomy and fossil formation in the Green River formation, southwest Wyoming. I developed a module for use in an online course for pre- and in-service teachers, with the intent of enhancing teacher understanding of earth system science and fossil formation. To gauge changes in content knowledge, an assessment was given prior to and after module completion, and the scores were analyzed. The module used the problem-based learning (PBL) teaching method coupled with an online learning delivery method. Techniques to improve learning by both methods were observed and are discussed, with the intention of making online problem-based learning of earth system science concepts a valuable and effective instructional delivery tool.

Background:

The module developed for this project was placed within an existing instructional format designed by the Earth System Science Education Alliance (ESSEA). The ESSEA modules have a unique and beneficial format that is designed to make students examine the interconnectedness of the earth system. Each ESSEA learning module is built around a central natural event (i.e. an earthquake; climate change; volcanic eruption). Students in the course investigate the effect of that event on the various spheres that make up the earth system (hydrosphere, lithosphere, biosphere and atmosphere). Initially, students

investigate single chains of effects - the effect of the event on one sphere (e.g., the effect of a hurricane on the biosphere). As the course progresses, students expand the scope to include multiple causal chains – the effect of the event on one sphere, then how that sphere affects another sphere and so on. To continue the example used above; students would report on the effect of a hurricane on the biosphere, then how that change in the biosphere would affect the lithosphere, and then how that lithosphere change would affect the hydrosphere. Causal chains can be as long as students determine, with as many paths and re-connections as needed. Using the causal chain method, students are forced to investigate an earth system event from many angles and with multiple effects. Additionally, this format reinforces the inter-related nature of the spheres that make up the earth science system.

The Earth System Science Education Alliance modules also utilize PBL, which is simply defined as a, “method of instruction that uses problems as a context for students to acquire problem-solving skills and basic knowledge” (Donnelly, 2004). Problem-Based Learning involves hands-on learning skills applied to a specific scenario. Learning in this way is driven by the student, rather than the teacher; thus, PBL is a form of inquiry-based learning as well. Problem-Based Learning was developed by the McMaster Medical School in Canada, with the purpose of teaching medical students to apply their knowledge to a practical situation (Savin-Baden, 2007). The significant benefits of PBL include allowing students to discover and master concepts on their own, to apply knowledge to

new situations, and to build problem-solving skills. PBL is engaging, collaborative and learner-centered (Donnelly, 2004). The hands-on aspects of PBL encourage students to re-think their understandings and potential misconceptions, leading to improved comprehension of concepts (Bulunuz & Jarrett, 2009).

Problem-based learning has an innate appeal to both teachers and students because it appeals to their natural curiosity and desire to solve problems. Beyond that innate appeal, PBL has been evaluated for its effect on learning and cognition, thus making it a desirable learning strategy as well. In comparison to traditional learning methods, PBL enhances student meta-cognition (student perceptions of their thinking) and builds broad thinking skills (Downing et al., 2009).

Problem-Based Learning has a definite process of steps designed to facilitate independent learning, collaborative review with team-members, critical thinking and problem-solving. The identifying characteristics of PBL are: 1) the real-world situations are open-ended and have no right answer, 2) teams approach the problem, identify what they do and don't know, and collaboratively develop credible possible solutions to the problem, and 3) the learning is self-directed and student-centered, with instructors serving as facilitators rather than providers of information (Savin-Baden, 2007). Another key feature of PBL is its flexibility - PBL can be applied across a variety of subjects and in diverse contexts, with students learning through the problem rather than by memorizing.

As indicated by its title, the main feature of PBL is that learning is centered on problem scenarios rather than discrete subjects (Savin-Baden, 2007).

The Earth System Science Education Alliance was created in 2000 by the Center for Educational Technologies and the Institute for Global Environmental Strategies (IGES). The alliance developed high-end online courses that teach earth system science and encourage communication and cooperation among the teacher learners (Wheeling Jesuit University/Center for Educational Technologies, 1999-2009). ESSEA was designed to strengthen teacher understanding of earth system science, and to build a self-sustaining structure for the courses (Schwerin et al., 2006). Today, the goals of ESSEA are, "to support educational institutions across the country in offering a series of online ESS courses for teachers. Working in collaborative groups, teachers earn graduate or continuing education credit while solving problems, building models, and designing classroom activities" (Institute for Global Environmental Strategies, 2000-2009).

The benefits of the online-learning format used for ESSEA modules is that the design both meets the needs of geographically-diverse learners (Collis & Moonen, 2005), while still building content knowledge. Utilizing an online discussion board for student contributions is a pedagogically effective method of engaging students and encouraging students to examine their content understandings (Leng et al., 2009). Online delivery of earth system science

concepts, specifically, allows students to feel more engaged with the content, and promotes deep learning (Dong et al., 2009).

Learning modules in the ESSEA program center around an event, and then students examine the effects of that event on the land, air, water and life of Earth (Figure 1). The module developed for this project, Analyzing Preservation Bias in Green River Formation Fish Fossils, required a significantly different view, and one that the ESSEA program had not encountered before. The Preservation Bias module focused on an event in the past, and required students to investigate and analyze how the earth system spheres intertwined to create the event (Figure 2). This 'inverse' view of the typical ESSEA module format was a distinct challenge in the development and inclusion of the module, resulting in many adjustments and compromises. One significant adjustment was to change the crux of the module away from analyzing preservation bias and toward a natural event like mass fish mortality. A resulting compromise was to make the preservation bias analysis an optional part of the module.

Designing and developing the Preservation Bias module was a cooperative effort between Fossil Butte National Monument, ESSEA, IGES and the Department of Geology at Utah State University, and could not have been completed without their help.

Geologic Setting

Fossil Butte National Monument is located near Kemmerer Wyoming and serves to protect and research the fossils of the Green River Formation. The Green River Formation is made up of laminated limestone, mudstone and volcanic ash from three Eocene regional lakes: Lake Gosiute, Lake Uinta and Fossil Lake (National Park Service, 2009). These lakes were likely warm monomictic with cold and deep bottom layers (Ferber & Wells, 1995). As a result of the unique conditions in the lakes, or the region at the time, the Green River Formation contains countless fish fossils, many exceptionally well-preserved; however three layers contain examples of mass fish mortality (McGrew & Casilliano, 1975). The fossils in the Green River Formation, and thus in Fossil Butte National Monument, are generally highly articulated, with the soft tissues often preserved, and represent a nearly complete record of the Eocene ecosystem in the region (Biaggi & Buchheim, 1999). As a result, the Green River Formation is considered a Lagerstätte (Illinois State Museum, 2003), which is a collection of fossils known for their exceptional preservation or diversity, sometimes both (Allaby & Allaby, 1999).

The Green River Formation is 53.5 – 48.5 my old (Smith et al., 2003) and contains numerous examples of mass fish mortality, wherein a section of a single layer exhibits a concentration of well-preserved fish that appear to have died at the same time. In order to produce these layers, burial must have been rapid, so

that the layers were not heavily bioturbated. In the ancient Fossil Lake, the average sedimentation rate in the center of the lake (which encompasses present-day Fossil Butte National Monument) was substantially higher than the rate at the edges of the lake (Smith et al., 2008). Fast burial, specifically by calcium carbonate precipitation (Bottjer et al., 2002) is conducive to producing layers of well-preserved fossils, as well as anoxic bottom layers. Algal blooms are a possible source of annual anoxic conditions that lead to mass mortality, as well as fluctuating salinity levels (McGrew, 1975).

Fossil Butte National Monument has a small research quarry on-site, where excavations are conducted during the summer months by volunteers and rangers. Fossils identified and/or collected from this quarry are recorded in field notebooks, with the data ultimately put into an electronic dataset maintained by the Fossil Butte National Monument staff. The data set contains a record of fossils found at the quarry from 1998 to 2007, and can be accessed via the park web page

(<http://www.nps.gov/fobu/planyourvisit/upload/Fossil%20Lake%20Quarry%20data%201998-2007.xls>). For each fossil found, information recorded includes: the species name (if possible), length, side it is preserved on (left or right), % articulation, orientation, location in the layer (on surface of layer or in the rock), and depth below the bottom ash layer (Fossil Butte National Monument, 2009).

Methods:

The original idea for the Preservation Bias module in the ESSEA course was to use this dataset as the primary scenario for the PBL activity. Students were to analyze the quarry dataset for possible preservation bias of the fossil fish (e.g., Was one species more likely to be 100% articulated than another? Was there a bias toward a certain size class being preserved in the record?), and in the process they would learn about taphonomy, paleontology of the region and fossil formation. However, upon consultation with the directors and experts at ESSEA, it became apparent that, due to the emphasis on the analysis of the effects of natural events, the fossil quarry dataset analysis (which requires human interpretation of in-situ fossils) could only be an optional part of the module, and not the main objective. Therefore, the main objective of the ESSEA module developed for this project became determining the specific sphere conditions of the lithosphere, hydrosphere, biosphere, and atmosphere that led to the mass mortality fish layers in the Green River Formation. The task of analyzing the Fossil Butte National Monument dataset is an additional, and optional, objective.

The process of developing the Mass Fish Mortality module began with collating information about the Green River Formation, Fossil Butte National Monument and fossil formation for the students in the course. The ESSEA module template was used, thus allowing insertion of background information,

hands-on learning activities about fossil formation, and graphics to familiarize the student with the site and its natural history. A preliminary version of the module was sent to reviewers at ESSEA for their input. Suggestions were submitted, and changes were made to the module. This process of review and change was conducted several times, until the module was ready for the 'pilot' phase. The module was piloted twice, as part of a spring semester 2009 course, and a summer semester 2009 course in the Geology Department at Utah State University. A public preview of the module is available at http://esseacourses.strategies.org/module.php?module_id=88.

During fall semester 2008, a trial of analyzing the Fossil Butte National Monument dataset for preservation bias was conducted by undergraduate students in a Paleobiology course within the Department of Geology at Utah State University. This face-to-face pilot was instrumental in determining how the online students would conduct the preservation bias analysis, and was qualitatively successful, i.e., students were able to analyze the dataset, and found a small possible preservation bias with regard to fossil fish orientation. Unfortunately, due to the specific requirements of the ESSEA module format, students in the online course were only able to conduct a preliminary analysis of the Fossil Butte National Monument dataset. Instead, students in the online course devoted their time and effort to conducting an ESSEA analysis of the factors and spheres that led to mass mortality fish layers, an equally valuable educational objective.

The ESSEA course was advertised in multiple ways, all aimed at attracting teachers who need lane-change or re-licensure credits. Direct invitations to take the course were sent to all middle- and high-school science teachers in the Logan City and Cache County school districts. An announcement of the course appeared on the Utah State Office of Education (USOE) professional development web site. Permission was granted by the USOE to award CACTUS credits for the course (CACTUS is a mechanism for teachers to gain state-sanctioned professional development credits). The course offering was announced in the National Science Teachers' Association Reports! publication, as well as the Utah Science Teachers' Association web page. In an effort to attract pre-service teachers, direct messages were sent to the science methods faculty of the Utah State University School of Teacher Education and Leadership.

Anticipating much interest in the course, yet wanting to create a feeling of teamwork amongst the members, the course was capped at 12 students. This concern was misplaced, however, as enrollments were consistently low (2 – 3 students each semester). Upon reflection, there are several potential reasons for the consistently low enrollment, ranging from course workload and expectations, to other demands for a teacher's time. Further information about the enrollment issues appear in the discussion section below.

Online learning has tremendous potential and a number of challenges. A significant benefit of online learning is that it is accessible to off-campus and non-

traditional students. This allows them to complete their educations or expand their learning, something important to the mission of a land-grant university like Utah State University. Another advantage is that students in online courses often feel more in contact with the instructor, due to the one-on-one nature of the communication, and the feedback or response from the instructor (Donnelly, 2004). Online courses that require collaboration between the students – via a discussion area, or threaded topics – further enhance student involvement in and motivation for the course (Donnelly, 2004).

Significant challenges to online learning persist. Such courses require students to be quite savvy about computers and electronic communication, something that many older and returning students may lack. This lack of technical skill and support can result in significant levels of student frustration, and potential withdrawal from the course. One student in the course for this project quickly reached frustration at not having the technological skills she felt she needed. The student hastily dropped the course, but after long consultation with the instructor, she re-enrolled. For the remainder of the semester, the instructor provided substantial assistance and comfort to the student, in order to help her complete the course. Other technological challenges exist, primarily problems with maintaining consistent physical electronic connections (Donnelly, 2004). Students in remote or isolated regions can be hindered by the connection hardware available to them, making completion of an online course a challenge.

In addition to the general obstacles of online learning, Problem Based Learning in an online environment has unique barriers and powerful benefits as well. The scenario or task the course is built around needs to be authentic to the learner, i.e. a real-life (or potentially real-life) event, so the learner has more attachment to the problem (Donnelly, 2004). The real-life nature of PBL also results in the method's strongest benefit: it requires students to use and apply knowledge. PBL also requires collaboration and communication between the students. This can be a challenge in face-to-face classes, but is much easier to do with an online course. The design of a PBL course directs students to think critically about a problem, resulting in stronger critical thinking skills (Sendag & Odabasi, 2009). These skills lead to creating contributing members of society. Applying knowledge, sharing information, and solving problems are all highly desirable and valuable skills in the work force. Thus, PBL develops and trains students to use skills they will need in their careers.

Assessment:

In order to measure the effect of the PBL module developed for this project on student content knowledge, pre- and post-module assessments were designed. The assessment initially consisted of 10 multiple-choice questions about fossils, fossil formation, taphonomy and earth science concepts, but was later expanded to 14 queries. Questions were first developed from a list of learning objectives for the module (created by the instructor), focusing on

enduring concepts that would be essential knowledge in the earth sciences. The enduring concepts desired with the module are: 1) that the earth changes over time; 2) taphonomy and the myriad ways it can affect fossilization; 3) why not all fossils are preserved in the fossil record; 4) that fossilization requires an uncommon set of conditions; and 5) how to scientifically analyze a data set.

Recognizing that the initial assessment emphasized thinking at lower levels of Bloom's Taxonomy, several of the questions were rewritten to measure higher-level thinking skills (see figure 4). In an effort to address misconceptions about earth system science, new assessment questions were developed. These questions were designed by consulting state earth science standards, locating ones that could potentially be misunderstood, and writing questions about them. On those questions, a misconception was intentionally put in as one of the possible answer choices, with the hope of measuring the prevalence of teacher misconceptions about earth system science concepts.

To further develop valid assessments, the author then consulted with test question writing experts Dr. Kimberly Lott, professor in the School of Teacher Education and Leadership at Utah State University, and Dr. Hilarie Davis, founder of the Technology for Learning Consortium. By reviewing question and answer wording, logical student responses, and potential ambiguous and redundant answer options, the assessment questions were strongly enhanced by Dr. Lott. Specifically, we attempted to prevent students from easily deducing the

correct answer from clues in the questions or answers, rather than applying content knowledge to find the correct answer, and we re-phrased several questions to guide the students to think about the content on a deeper level (accessing higher-order thinking levels according to Bloom's Taxonomy). The improved questions were then piloted in one of Dr. Lott's teaching methods courses, with pre-service science teachers taking the assessment and providing feedback. With the comments from Dr. Lott and her class, the questions were then sent to Dr. Davis for refinement. Dr. Davis assisted with matching the question format to the typical ESSEA format, and with making the questions assess thinking on a deeper content level. Dr. Davis then consulted another assessment expert, Dr. Bradford Davey of Pepperdine University, who contributed additional content questions that addressed student understandings of the fossil record and the process of fossilization. Finally, the author added an open-ended question, so the entire assessment ended up consisting of 15 questions (see appendix A).

Results:

The process of refining the assessment questions took several months. As a result, the first students who completed the module only had 12 questions in their assessment, while the second group had the full 15 question assessment. The module was piloted first in spring semester 2009. Two students completed the course that semester, and two more finished the course in summer semester

2009. The pre-course and post-module assessment scores appear in Table 1. While the geographic diversity of students in the course was interesting (two were nearby, one was in Boston, and one was in Germany), the sample size was quite small. However, preliminary trends can be seen in the small sample size. Despite an offer of 80% tuition reimbursement, it was very difficult to get students to sign up for the course. Possible reasons for the small enrollment are discussed below.

Discussion:

Statistical analysis of the pre- and post-course multiple-choice assessment data was conducted using the Wilcoxon Paired- Sample test ($p < 0.05$), with the result that there were no significant differences between the pre- and post-course assessments.

Statistical analysis of the change in rubric scores between the first and third modules over Cycles A, B and C was conducted using both the Paired Sample T-Test and the Wilcoxon Paired-Sample test. With both tests a significant improvement ($p < 0.05$) was found for the Cycle A and the Cycle C rubric scores. No significant change was found for the Cycle B scores.

Several of the content assessment questions were specifically written to gauge student understanding about common science misconceptions. In reviewing student performance on those specific assessment questions (Table

3), the students correctly answered each of those questions in the pre- and post-course assessments. It is clear that students in the course already understood the concepts correctly and did not fall victim to the misconceptions that non-science majors typically do.

The results of the pre- and post-assessments are ambiguous at best. On the one hand, it is apparent that students either understand the concepts in the assessment right from the start, or know how to find the information they need to answer the questions. There was no requirement to take the assessment without assistance, and one student informed the instructor that they had taken time to research the correct answers. On the other hand, there is no clear evidence of an improvement in scores over the duration of the course, a trend that carried across other modules as well (Table 2). This lack of improvement is due to two main factors: the pace of the course, and the weight of the assessment on the final grade.

Even for a typical college student, the course is fast-paced. The workload and speed are compounded when the students are working teachers while taking the course. That was the situation for the spring semester 2009 course: both students were full-time teachers taking the course in their free time. As educators know, teaching in the K-12 system is extraordinarily demanding and all teachers take work home with them and devote weekend time to preparing for class. Adding in a fast-paced, involved course to the existing constraints of an

educator's time means that something will receive less effort. It is expected that teachers would devote much more of their time and mental energy to their paying jobs than to a college course.

For the summer semester 2009 course, while both students were employed educators, they were not actively teaching during the time of the course. However, summer is typically a time for educators to attend conferences, workshops and training, which results in less time to devote to a course that required nearly daily work. On top of the other demands on a teacher's time, the summer semester is already highly compressed, which compacted all of the course deadlines, and this course was re-structured to fit within the only 2 months a teacher has off from work: June and July. Therefore, the author believes that students in the course were fatigued and not motivated to improve their score by the time the post-module assessment came around.

The grading for the ESSEA course is up to the instructor. However, it is relatively easy for students in the course to determine the weight of the various assignments and assessments. In a typical module, a student completes 4 assignments (multiple-page research papers) and 2 assessments (multiple-choice quizzes). It is apparent that the majority of a student's grade is determined from the submitted written assignments, and the assessments are a small percentage of the final grade. Students are able to figure out where they should spend the most of their time and energy and they act accordingly. As a result,

they do not put as much effort into the assessments as they do to the written analyses.

Another method of assessing student learning is built-in to the ESSEA online module, however, and it is done by using rubric scores. Each cycle of an ESSEA module requires the student to submit a written document that is then assessed using rubrics (Appendix B). In general, the rubrics evaluate the student's quality of reasoning, accuracy of information, and quality of writing. Over the duration of each ESSEA course, as students progress through Cycle A, Cycle B and Cycle C components, their success in understanding earth system science and sphere interactions can be measured by the rubric scores. Table 4 shows the progression of student rubric scores for all of the ESSEA courses taught at Utah State University. Each module consists of Cycles A, B and C and the course is made up of 3 modules. Table 4 is arranged to illustrate the change in student rubric scores as they progressed through the modules, and shows a marked improvement over the duration of the course. Figures 5 – 7 illustrate this advance in scores through the 3 modules. Improvements in rubric scores are readily apparent in all Cycles of each module; however, it is important to note that Cycle B in each module is a team-based cycle. Thus, the rubric scores are generally applied to the entire team (unless the instructor chooses not to, as was done on occasion). The Cycle B scores do not show as dramatic an improvement as the other Cycles for this reason.

The preservation bias analysis portion of the module was piloted in a face-to-face campus class during fall semester 2008. This pilot was beneficial in testing proof-of-concept and in assessing student understanding of taphonomy and analyzing a data set. Students in the pilot class were asked to brainstorm a potential preservation bias to analyze in the data set (applying their understanding of taphonomy), then to team up to conduct and report on the analysis. Student teams successfully investigated preservation bias in the data set and presented their findings in an oral and written report. Overall, the students did not find clear evidence for preservation bias in their analysis, except for a possible small bias with regard to fossil fish orientation. The qualitative success of this pilot confirmed the practicality of adding preservation bias analysis to the online ESSEA module.

Suggestions for further work:

Online learning is a valuable tool that enhances student access to courses and adds flexibility to student choices. Problem Based Learning is a powerful teaching and learning strategy that builds critical thinking skills and prepares students for the working world. An online PBL course (like the ESSEA offerings) is a highly desirable and potent combination of these important ways of learning. There are challenges to both online learning and the ESSEA courses however, some of which can be addressed in the future, and some which are inherent to the design.

The ESSEA courses are aimed at teachers, both pre- and in-service, and are a useful way for in-service teachers to gain credits for lane changes or re-licensure. However, it would be best to teach them during the summer semester, rather than during the school year. While they are powerful courses, the ESSEA courses require much time and effort and offering them when teachers are already at maximum exertion with their jobs is a disincentive. That said, even during the summer, completing an ESSEA course takes teachers away from other commitments (workshops, travel, second jobs, family) and lessens their 'recharge time,' something closely protected by educators. The workload and timing of the course is a significant factor in the low enrollment numbers. Another factor is that there are numerous free, and easier ways, to gain credits or re-licensure points, and teachers are unwilling to pay tuition (even if much of it is reimbursed) for something they can get elsewhere at no cost and for far less effort. Even if these other venues toward credits or points are not relevant to their classroom, or not intellectually challenging, it doesn't matter to teachers. On a re-licensure application, credit is credit, and there is no examination on the value of the credit.

The online format of the class is a benefit for most educators; however it can result in a lessened commitment when compared with a face-to-face class. For that reason, it might be helpful to add a small face-to-face component to the course, such as regular virtual class meetings (via a webcam and interactive

utility like Wimba), or a social gathering at the start and end of the course (for those students living nearby).

Possible ways to increase enrollment include changing the course name, adjusting the scheduling of the course, and increasing the benefit value of the course. There are limitations on course name length, but students might be more attracted to a course with an enticing title rather than the mundane titles of the ESSEA courses taught for this project. Offering the course over a longer period of time, which may be difficult to do in a university system, or reducing the modules in each course might make the workload more palatable to teachers. Finally, enhancing the content objectives so they are more directly (and readily) applicable to the classroom and state standards, or decreasing the initial financial outlay might attract more interested students.

Teamwork is a key and useful component of Problem-Based Learning (Donnelly, 2004), however, it can also be the most problematic, particularly with an online format. The students involved in this study consistently reported concerns about their team members. Complaints ranged from limited accessibility of a team member, incompatible schedules for collaboration, and differences over each member's contribution level to charges of one member skating on the work of the other. The perception of inequality between team members significantly affected the team's work in a negative way.

In the future, this consistent source of potential conflict should be addressed. While somewhat more challenging to accomplish with an online course, it would be beneficial to devote class time to teaching teamwork skills and conflict management techniques. On the other hand, it is possible that teamwork problems are inherent when working with educators. After observing teachers for many years, the author has noticed that educators possess a significant aversion to teamwork, and a strong preference to work individually. This quality is likely due to, and reinforced by, educators being 'in charge' of their classrooms and lessons every teaching day. Additionally, the movement for increased accountability of teachers and teaching has required educators to defend the value of what goes on in their classrooms. It is easier for a teacher to justify their own work, and lesson choices, than work done as part of a team. For future courses, guiding teachers to go beyond their initial aversion to teamwork at the start of the ESSEA courses would be a powerful accomplishment.

The original idea for this module did not fit well within the format of the ESSEA philosophy and structure. In the author's opinion, the original plan (Analyzing Preservation Bias) remains an appealing and powerful PBL opportunity. The effectiveness of, and interest in, conducting the analysis was evident during the face-to-face pilot in the Paleobiology course during the spring semester 2009. Therefore, we recommend that a future class be centered on the preservation bias analysis. Alternately, adding the preservation bias analysis to

an existing course (online or face-to-face) could enhance teamwork, and critical thinking skills in that class.

Conclusions:

The original goal of this project was to assess earth system science content learning from an online course involving the analysis of preservation bias in a fossil data set. In the process of designing and teaching the resulting course module, we learned that analyzing the effects of natural events on the earth system is more applicable to the ESSEA format than analyzing preservation bias in a fossil data set. We also encountered teaching challenges that are not only unique to the online environment, but also to the audience of educators. While pre- and post-module assessment scores did not significantly change, the process of analyzing and evaluating a real-life scenario for impacts on the earth system is valuable and forces students to enhance content knowledge.

TABLES

Semester	Student	Pre-course score	Post-course score	Change
Spring 2009	DW	88%	91%	+ 3%
Spring 2009	GS	73%	73%	0%
Summer 2009	MU	100%	93%	- 7%
Summer 2009	MC	86%	86%	0%

Table 1: Analyzing Preservation Bias module student pre- and post-course content assessment scores.

Module	Student	Pre-course score	Post-course score	Change
Wind Power	MU	80%	60%	- 20%
Wind Power	MC	90%	80%	- 10%
Methane	MU	60%	50%	- 10%
Methane	MC	60%	70%	+ 10%

Table 2: Pre- and post-assessment scores for other modules.

Question # (addressing misconceptions)	Pre-module answer (MU, MC)	Post-module answer (MU, MC)
1	4, 4	4,4
3	3,3	3,3
13	4,4	4,4

Table 3: Student answers for assessment questions intentionally addressing common misconceptions.

Student initials							
Cycle A	BB	RB	AO	DW	GS	MC	MU
1 st Module	3.25	2.875	3.25	3.25	2.875	3	3.875
2nd Module	3.5	3	3.625	3.5	3.25	3.5	4
3rd Module	3.625	3.375	3.625	3.625	3.375	3.75	3.9867

Cycle B	BB	RB	AO	DW	GS	MC	MU
1 st Module	3.75	3.75	3.75	3.75	3.75	3.5	3.25
2nd Module	3.75	3.75	3.75	3.75	3.75	4	4
3rd Module	3.75	3.5	3.5	3.75	3.5	4	4

Cycle C	BB	RB	AO	DW	GS	MC	MU
1 st Module	2	3	2.6	2	3	3.4	3.2
2nd Module	3.2	3.4	3.8	3.2	3.4	3.6	3.8
3rd Module	3.8	3.4	4	3.8	3.4	3.2	4

Table 4: Average faculty-graded rubric scores for all students taking ESSEA courses taught at USU – arranged to show student progress over duration of course.

FIGURES

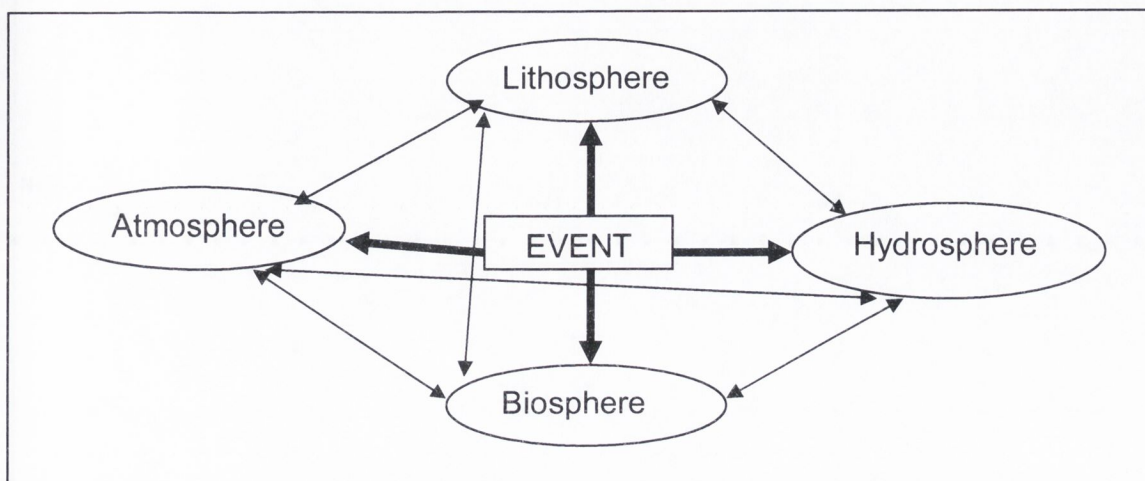


Figure 1: Schematic of a typical ESSEA module, showing the emphasis on the effect of the event on the spheres.

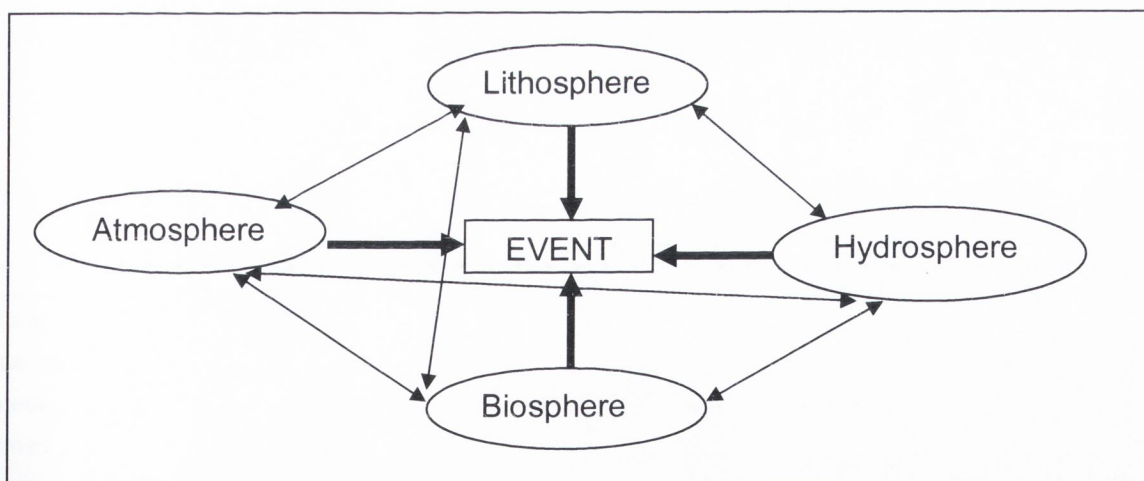


Figure 2: Schematic of module developed for this project, showing the emphasis on the interaction of the spheres needed to create the event.

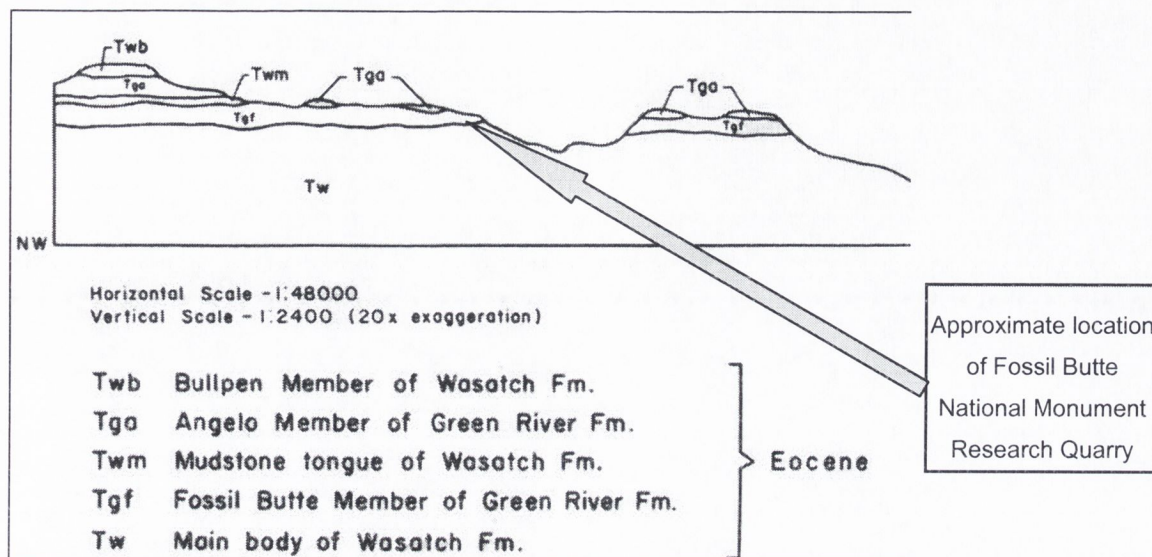


Figure 3: NW-SE section across Fossil Butte National Monument, Sage and Kemmerer quadrangles (after Rubey et al. 1968a and 1968b).

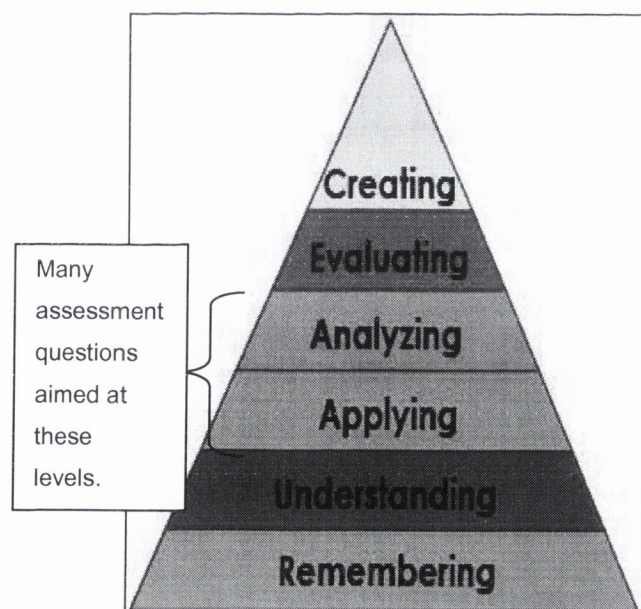


Figure 4: In 1956, Benjamin Bloom developed a classification of levels of intellectual behavior important in learning. During the 1990's a new group of cognitive psychologists, lead by a former student of Bloom's, updated the taxonomy reflecting relevance to modern requirements of learning and work. This graphic is the Revised Bloom's Taxonomy (after Overbaugh & Schultz, 2009)

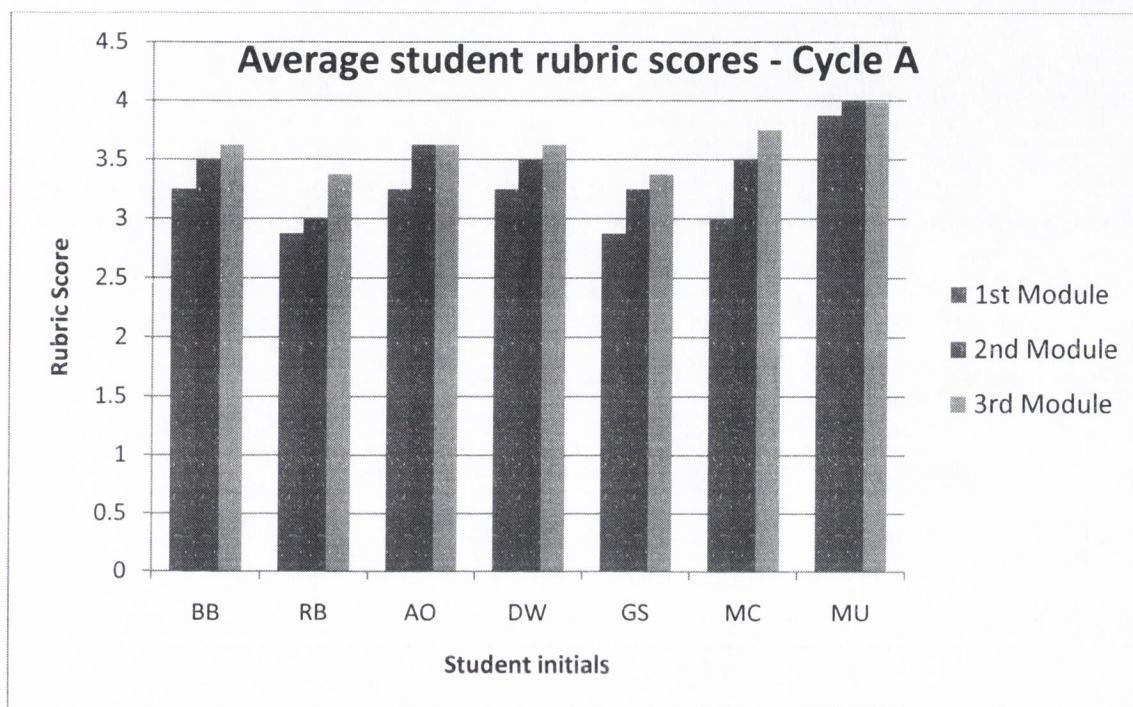


Figure 5: Graph of student Cycle A scores as course progresses.

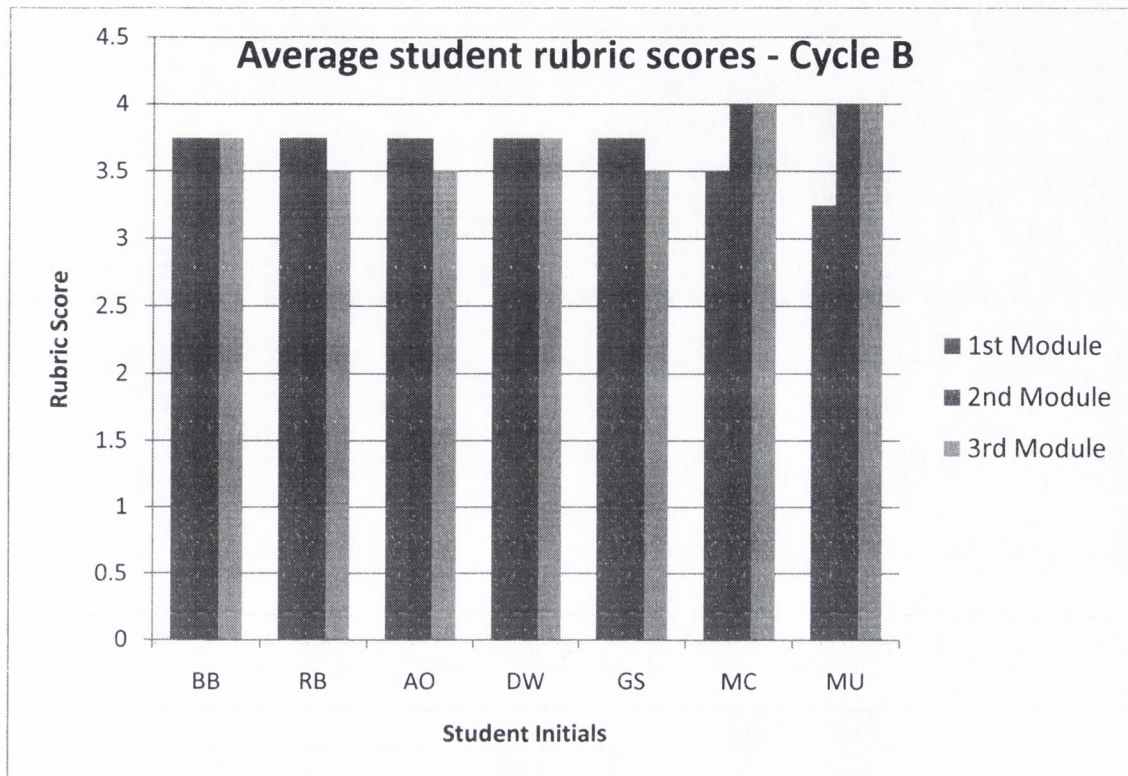


Figure 6: Graph of student Cycle B scores as course progresses. (Note: Cycle B is a team-based module, thus most students received a team-wide score)

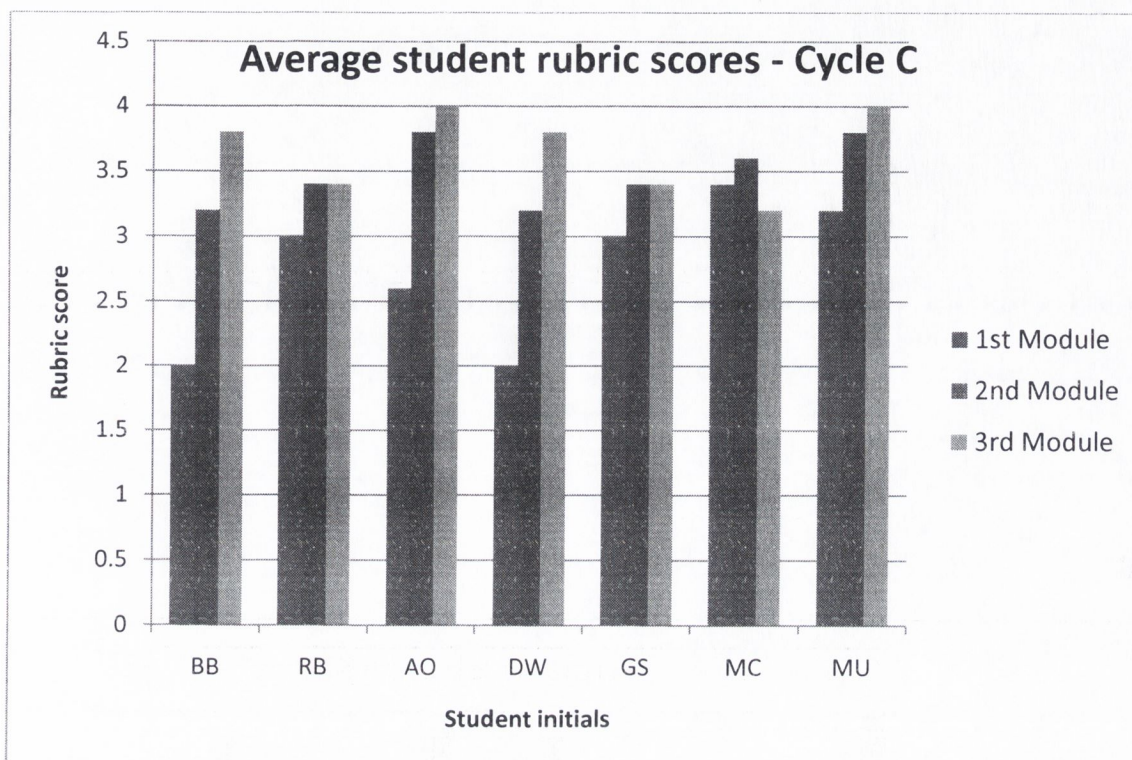


Figure 7: Graph of student Cycle C scores as course progresses.

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APPENDICES

Appendix A:

Assessment Questions

1. When comparing fossils from the western edge of Africa with those from the eastern edge of South America, a paleontologist reveals they are nearly identical in age and appearance. What is the best explanation of her findings?
 - A. The fossils must have been moved from one location to another.
 - B. Fossils separated by great distances prove the species was migratory.
 - C. Different species evolved independently while adopting identical features.
 - D. The two areas where the fossils were found might have been in contact at one time.

2. Fossils of tropical fish are found high in the hills of Montana. What does this information reveal about the conditions of the Earth at the time those fossils were formed?
 - A. It shows that fish now living in tropical areas could live in the much cooler Montana area at the time the fossils were formed.
 - B. The rock that the fossils were found in must have been a tropical sea bed at one time.
 - C. The sea was much deeper at the time the fossils were formed.
 - D. Fossils of fish that far north suggest glaciation occurred much later than first believed.

3. A group of fossils were found in layered sedimentary rock. What might we be best able to conclude about the fossils from what we can observe on location?
 - A. Sea levels were much higher then.
 - B. This area must have experienced uplifting since the fossils were made.
 - C. The position of the fossils relative to each other suggests their relative ages.
 - D. The environmental conditions now are much different from the environmental conditions at the time the fossils were formed.

4. Once a fossil is formed, which of the following best explain how it might become exposed?
 - A. Harder substances like fossils naturally move to the surface over time
 - B. Weathering and erosion slowly remove material
 - C. Because fossils form from living organisms, they are already near the surface
 - D. More often, fossils are not exposed but transported to a new location where they are discovered

5. What does taphonomy tell earth scientists about the past?
- A. how living things die
 - B. the conditions that lead to new species formation
 - C. the process of fossil preservation
 - D. what happens to an organism after it dies
6. Which of the following describes an ideal process that forms intact fossils?
- A. something dies, is buried quickly, living parts replaced by minerals
 - B. something dies, decomposes, is buried quickly, living parts replaced by minerals
 - C. something dies, decomposes, is buried slowly, and hardens
 - D. something dies, is buried slowly, and hardens
7. Which of the following conditions and/or events would hinder fossil formation?
- A. scavenging
 - B. quick burial
 - C. volcanic ash fall
 - D. flood
8. What is the definition of paleontology?
- A. study of rocks and minerals
 - B. study of fossils and what they tell us about past life
 - C. study of ancient lakes and rivers
 - D. study of ancient climates and earth geography
9. While out hiking, you pick up a rock that has ripple marks on it. It looks like what you'd see in the shallows of a seashore today, and you conclude that the rock was formed under similar conditions in the past. What principle of geology are you applying?
- A. superposition
 - B. uniformitarianism
 - C. catastrophism
 - D. original horizontality
10. Fossils of palm trees are found in present day Wyoming. What is the most logical conclusion from this?

- A. that Wyoming was once nearer to the poles
- B. that Wyoming was never part of Pangaea
- C. that Wyoming had a different climate in the past
- D. that Wyoming had lakes at one time

11. What is the definition of fossil?

- A. remains of a living thing
- B. rocks that formed prior to 125 million years ago
- C. preserved evidence of a living thing
- D. an organism that dies

12. How long ago was Fossil Lake (near present-day Kemmerer Wyoming) teeming with life?

- A. 34 - 25 million years ago
- B. 55 - 34 million years ago
- C. 65 - 55 million years ago
- D. 24 - 5 million years ago

13. What can we conclude from 'gaps' in the fossil record?

- A. That the theory of evolution is incorrect
- B. That the fossilization process was different in the past
- C. That there are no transitional fossils
- D. Geological processes often disrupt or destroy fossils

14. Which of the following is not considered a type of fossil?

- A. mud
- B. coprolite
- C. footprint
- D. cast

15. What are three of the conditions needed to produce a Lagerstätten?

Appendix B.

ESSEA rubrics

Individual Reflection Rubric (Cycle A)

	4 Rating:	3 Rating:	2 Rating:	1 Rating:	0 Rating:
Personal Understanding: How do you explain this to yourself, "I think..."	A list of things you know and a list of questions about things you know you don't know or wonder about.	A list of questions you have about the situation.	A list of things you think you know about the situation.	A list of some ideas related to the topic.	Not present
Supported by reasons, "Because..."	You think through the situation even more by examining when your understanding might be accurate, or if it is accurate what the implications would be.	You analyze your prior knowledge to see if it makes sense.	You describe why you believe your understanding to be accurate or not accurate, such as based on some experience or related knowledge.	You give some reason, such as where you learned or hear about it.	Not present
Based on	You support your ideas with the best explanations and reasons you currently have.	You give some reasons for why you think what you think. This may include your personal experience,	You support your explanations with one or more examples.	You explain that you don't know why you think what you think.	Not present

Team Knowledge-Building Process		or things you have heard or learned.			
Questions	4 Rating: A rich list of	3 Rating: A rich list of	2 Rating: A rich list of	1 Rating: A rich list of	0 Rating: A rich list of
	questions (profound and trivial) with contributions from each participating team member.	questions (profound and trivial) with contributions from each participating team member.	questions (profound and trivial) with contributions from each participating team member.	questions (profound and trivial) with contributions from each participating team member.	questions (profound and trivial) with contributions from each participating team member.
Multiple perspectives on each question	Multiple perspectives are weighed as members begin to answer questions.	Different perspectives emerge as team members begin to answer questions.	More than one perspective is apparent as some members begin to answer some team questions.	Individual perspective is retained as separate since individual answers answer only their own questions.	Not present
Support for answers	Answers are partially supported and the kind of evidence needed to support them is described.	Answers are partially supported with evidence from science, popular research or testing.	Answers are supported.	Only answers are given without reasons.	Not present
List what needs to be done	A thorough investigation is planned and described with individual roles, types of resources	An investigation that builds on itself with steps for team members to	A list of tasks with roles and expectations is given.	The questions are divided up to be answered by different	Not present

Team Knowledge-Building Rubric (Cycle A)

	4 Rating:	3 Rating:	2 Rating:	1 Rating:	0 Rating:
Questions	A rich list of questions (profound and trivial) with contributions from each participating team member.	Each participating member contributes a variety of questions to the list.	Question list contains a variety of questions.	Question list is 5-6 questions in one or two categories.	Not present
Multiple perspectives on each question	Multiple perspectives are weighed as members begin to answer questions.	Different perspectives emerge as most members begin to answer most team questions.	More than one perspective is apparent as some members begin to answer some team questions.	Individual perspectives remain separate since individual members answer only their own questions.	Not present
Support for answers	Answers are partially supported and the kind of evidence needed to support them is described.	Answers are partially supported with evidence from experience, prior research or reading.	Answers are supportable.	Only answers are given, without reasons.	Not present
List what needs to be done	A thorough investigation is planned and described with individual roles, types of resources	An investigation that builds on itself with ways for team members to	A list of tasks with roles and expectations is given.	The questions are divided up to be answered by different	Not present

	and expected outcomes.	share as they do research, not just at the end.		group members.	
Creation of problem statement	A problem statement is described with an explanation about why it is important to the scenario.	A problem statement is discussed in terms of how it addresses the scenario.	A problem statement is accepted and an explanation is given for choosing this statement over others.	A problem statement is suggested and accepted without considering other options.	Not present

ESS Analysis Rubric (Cycle B)

	4 Rating:	3 Rating:	2 Rating:	1 Rating:	0 Rating:
Quality of Understanding: Accuracy of ideas, facts, statements (assertions) about interactions and causal chains	Response is complete and correct.	Mostly correct with <u>no</u> major errors, misconceptions or omissions. May contain up to 3 minor inaccuracies.	Partially correct with one or two significant omissions, content errors or more than 4 minor errors.	Misconceptions about key content in Earth system interactions.	Not present
Depth of Reasoning: Clarity and focus of supportable ideas, interactions and systemic relationships	Predicts future effects (e.g. positive feedback) or transfers understanding to evaluate other situations or recommends remediation (e.g. negative feedback).	Explains the processes responsible for the causal chains (S>S>S) in the event or context from a scientific perspective.	Describes interactions using cause and effect connections including secondary effects that unfold over time, event> sphere>sp here.	Describes what is happening in the system, including characteristics and direct effects of the event or context (event>sphere).	Not present
Evidence: Scope, detail and accuracy of the evidence supporting the relationship statements	Builds on data from reliable sources by manipulating the data to support claims (charts, graphs, maps, etc.) or refuting	Supports statements with data from reliable sources. Uses quantitative and qualitative data	Accurately uses and cites quantitative and qualitative data from reliable	Uses only quantitative or qualitative data or lacks adequate support for	Not present

	opposing positions with data or discussing ambiguity or error in the data.	appropriately.	sources.	statements, or lacks citations for some statements.	
Science Writing: ESS analysis is communicated clearly	Uses graphics (diagrams, graphs, pictures, video, etc) to support the text or has exemplary overview of the thesis or the writing style is particularly vivid, compelling, or creative.	Builds ideas across paragraphs and sections to support the main ideas.	Paragraphs support the main ideas/thesis. Sentence structure sometimes interferes with meaning.	The thesis/main ideas about the interactions are clearly stated. Grammatical errors do not interfere with the meaning.	Not present

PBL Individual Design Rubric (Cycle C)

	4 Rating:	3 Rating:	2 Rating:	1 Rating:	0 Rating:
Goal Focus: Setting expectations	Goals are clear and under-standable and focused on a few pivotal concepts.	Goals are clear and under-standable to your students.	Goals are under-standable to your students.	Goals are clearly stated.	Not present
Rethinking: Scenario and instructional plan	The scenario and activities are powerful in drawing out students personal under-standings about Earth Systems Science, causing them to rethink their ideas and to work together to build strong arguments for what they think they understand.	The scenario and activities are designed to draw out students' personal under-standings about Earth Systems Science, cause them to rethink those ideas and to think out loud together.	The scenario and activities are designed to cause students to rethink what they think they know and ask questions about what they don't know about Earth Systems Science.	The scenario and activities are designed to make Earth System Science intriguing to students so they want to learn more.	Not present
Resources: For student use	List of a variety of multiple resources (Books, Journals, CD ROMS, Internet, etc.) with interesting annotations.	List of multiple resources for student use from more than one source with a reason to use each.	List of resources for student use from one source (e.g. Internet URLs).	List of 3-4 resources for student use.	Not present
Assessment	Assessment is	Assessment is	Assessment is	Assessme	Not

: Criteria and indicators of success (for example, a rubric)	ongoing and standards-based involving students in seeing their own growth against clear criteria and indicators along a continuum of progress (Rubric).	ongoing, authentic and standards-based.	ongoing and standards-based.	nt is a test and an evaluation of the final presentation.	present
Personal Reflection: What you have learned	A detailed comparison of your initial understanding with your current understanding and an explanation of how your thinking changed through the PBL process.	An explanation of why you think your current understanding is more supportable than your original understanding based on your problem solving.	A comparison of your initial understanding (from Cycle A) with your current understanding.	A description of how you developed your current understanding.	Not present